SUBSURFACE AND PETROLEUM GEOLOGY OF

ASHTABULA COUNTY, OHIO

A Thesis

Presented in Partial Fulfillment of the Requirements
For the Degree Bachelor of Science

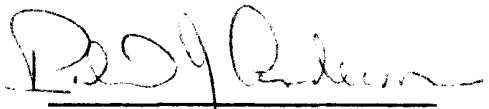
by

James W. Shoots

The Ohio State University

1985

Approved by:



Advisor
Department of Geology and
Mineralogy

CONTENTS

INTRODUCTION

Ashtabula County, Ohio is located in the very northeastern corner of the state (fig. 1). Its geographical boundaries include: Lake Erie to the north; Crawford and Erie Counties, Pennsylvania to the east; Trumbull County, Ohio to the south; and Geauga and Lake Counties to the west. All these surrounding areas were helpful in correlating well data to make inferences to trends that underlie Ashtabula County.

The study area is located on the northwestern flank of the Appalachian Basin. This basin is an elongate structural trough trending northeast-southwest. It stretches from New York to Alabama. Cambrian seas deposited large sections of carbonates in a depression that developed on the Precambrian surface (ref. 9, p. 17). The Taconic orogeny of Late Ordovician time filled the basin with large quantities of clastic material from the east and southeast. Again, in Middle Devonian time, new uplift, accompanying the Acadian Orogeny, deposited masses of marine and terrestrial materials in the same subsiding basin. A continuing orogeny, throughout the late Paleozoic, culminated in the Appalachian orogeny which occurred near the close of the Paleozoic (ref. 9, p. 17). At this time, the eastern flank of the Appalachian Basin was intensely folded, faulted, overthrust, and intruded by igneous bodies. The western flank, however, remained little deformed (ref. 4, p. 3.4).

To the west and northwest of the study area, the Cincinnati, Findlay, and Algonquin Arches are found. In general, these arches separate the Appalachian Basin from the Michigan and Illinois Basins. Structural development of these arches began during the Ordovician time and remained positive features until Late Pennsylvanian time.

Figure 1. AREA OF STUDY - ▨

THE PRECAMBRIAN SURFACE

In 1890, Edward Orton, Sr., third State Geologist of Ohio suggested that, "If we should descend deep enough below the surface, we should reach the limit of these stratified deposits and come to the great foundations which constitute the surface rocks in parts of Canada, New England, and the West. The granite of Plymouth Rock underlies the continent." In 1912, this hypothesis was seemingly confirmed by a well penetrating granite rocks in Hancock County, Ohio.

A total of 138 wells have now been drilled into the crystalline basement rocks in Ohio. Eight of these wells were drilled in Ashtabula County (fig. 2). They are not all similar to Plymouth Rock, but highly variable. These Precambrian age rocks are estimated to have reached their present form between 1.5 to 0.8 billion years ago. Their depths range from 3000 feet in western Ohio to 12,000 feet and more in eastern Ohio. In Ashtabula County, they are found at depths of approximately 7000 to 7500 feet. The Precambrian surface is known not to be a smooth, level one, but one that underwent considerable erosion before it was buried by Paleozoic sediments of the Cambrian Period.

From the deep wells drilled in Ohio, it can be concluded that Precambrian rocks east of west-central Ohio are in general metamorphic rocks with radiometric ages of 0.8 to 1.1 billion years. In western Ohio, they are in general, igneous rocks such as granite and its finer grained equivalents. This contrast has been interpreted by many

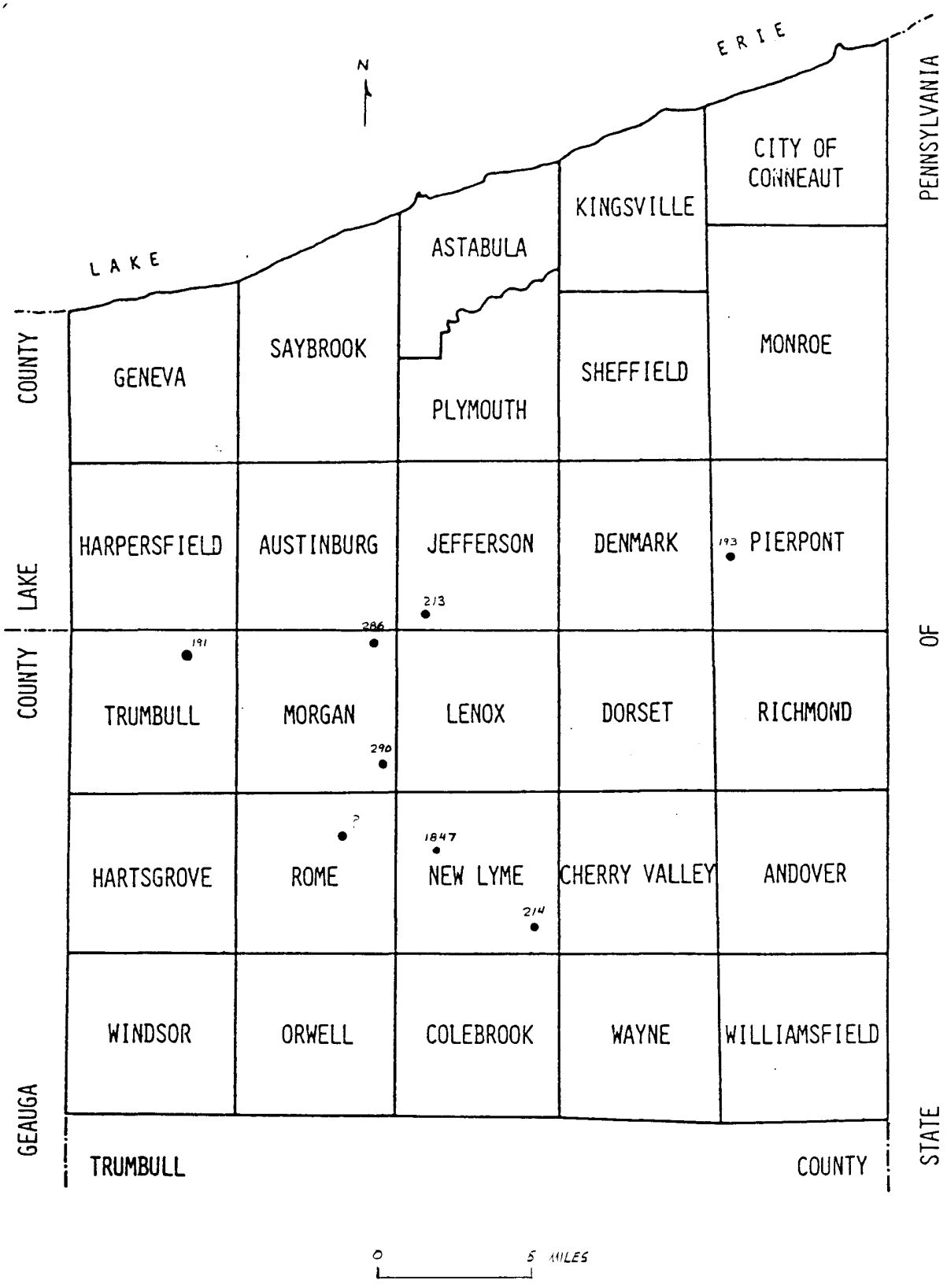


Figure 2. WELLS REACHING PRECAMBRIAN BASEMENT ROCK

geologists to be a structural feature known as the Grenville Front, named for exposures in Canada where metamorphic rocks of the Grenville Geologic Province are in contact with older igneous rocks of the Superior Geologic Province to the west (ref. 5, p. 3) (fig. 3). The Grenville Province is thought to underlie Ashtabula County and represent deeply eroded roots of a mountain range from a past orogenic event. In western Ohio, the Precambrian igneous rocks are a broad platform historically called the Cincinnati Arch. This could also be termed the Ohio-Indiana Platform (ref. 5, p. 4). Surrounding this platform are the Appalachian Basin to the east, the Michigan Basin to the north, and the Illinois Basin to the west. This Ohio-Indiana Platform may best be viewed as a relatively stable area, around which basinal areas have subsided, rather than an upwarped archlike structure. This area in which the Precambrian and overlying Paleozoic rocks dip away from this platform into the Appalachian Basin interestingly coincides with the proposed extension of the Grenville Front.

This same area has also been described as a fracture rift zone of Keweenawan age. This postulated rift zone is said to have undergone periodic reactivation to recurrent crustal stresses. The July 27, 1980 northern Kentucky earthquake may suggest that movement is still occurring along an ancient Precambrian zone of weakness.

The importance of the Precambrian surface to the oil and gas industry is intriguing. If the ancient surface valley and ridges are discovered, the draping of overlying Paleozoic sediments may have created traps for hydrocarbons. Also, if basement faults extend into the Paleozoic, additional traps may occur. If periodic reactivation of a rift

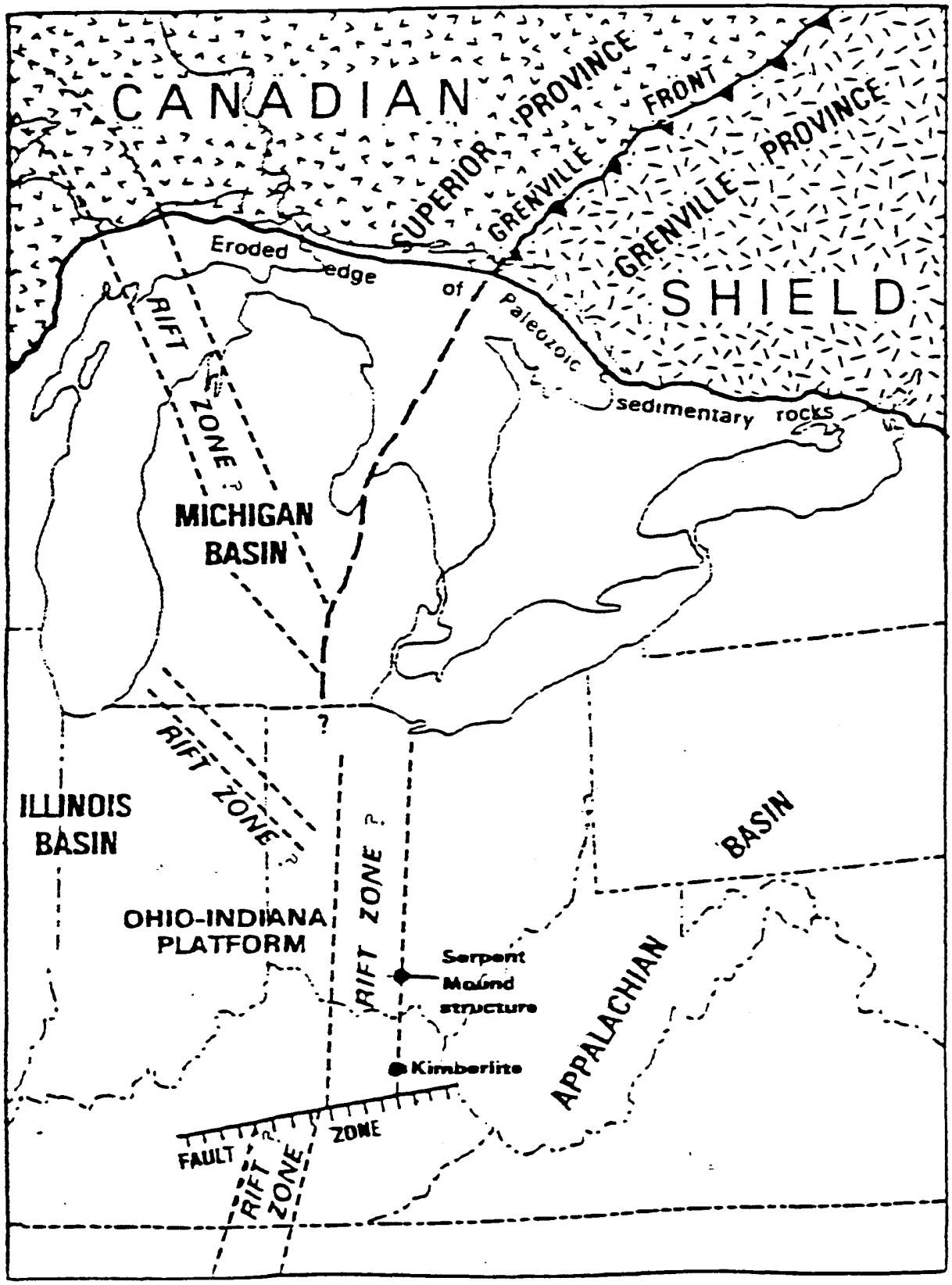


Figure 3. (Modified from Hansen, 1984.)

zone occurs and controls in part the pattern of deposition of Paleozoic sediments, stratigraphic traps may have occurred.

With limited information on the Precambrian surface in Ashtabula County, additional information will need to be gathered for these above postulations to be helpful to the oil and gas industry. Although our knowledge of the Precambrian basement rocks has progressed greatly since Orton's time, the new questions that have arisen are possibly more confusing than enlightening.

THE CAMBRIAN PERIOD

Early in the Paleozoic Era, the basins and arches that became prominent later in the Paleozoic were not sharply differentiated from the surrounding shelf (ref. 1). The Precambrian surface was exposed to erosional forces for an extensive period, before any deposition of Cambrian sediments. The Sauk transgressional sequence began in Precambrian time, and eventually covered the southern half of the craton in a great epeiric sea (fig. 4). The first sedimentary deposits were reworked sandstones that were left behind the advancing sea. In Ohio, this sand is called the Mt. Simon sandstone and is in general coarse to conglomeratic. The source of these sands was mainly granites of the Canadian Shield. These granites should have also produced enormous amounts of clay. Some geologists believe wind may have played an important role in removing this clay. Also, it may have been sifted from the sand by wave action.

As the sea advanced northward through Ohio, in eastern Ohio the Rome formation was deposited. It consists first, in Ashtabula County, of siltstones and fine-grained sandstones. As the sea deepened, a thick layer of pelletal and oolitic dolomite was deposited. Overlying this dolomite deposit are shales with dolomitic fragments. In Ohio, this is termed the Conasauga Formation.

Overlying the Conasauga in central Ohio is the Kerbel Formation. This is a fine-grained sandstone that coarsens upward. In the same stratigraphic position in northeastern Ohio is also a sandstone. This is not yet mapped as the Kerbel, but ultimately probably will be (ref. 7, p. 67).

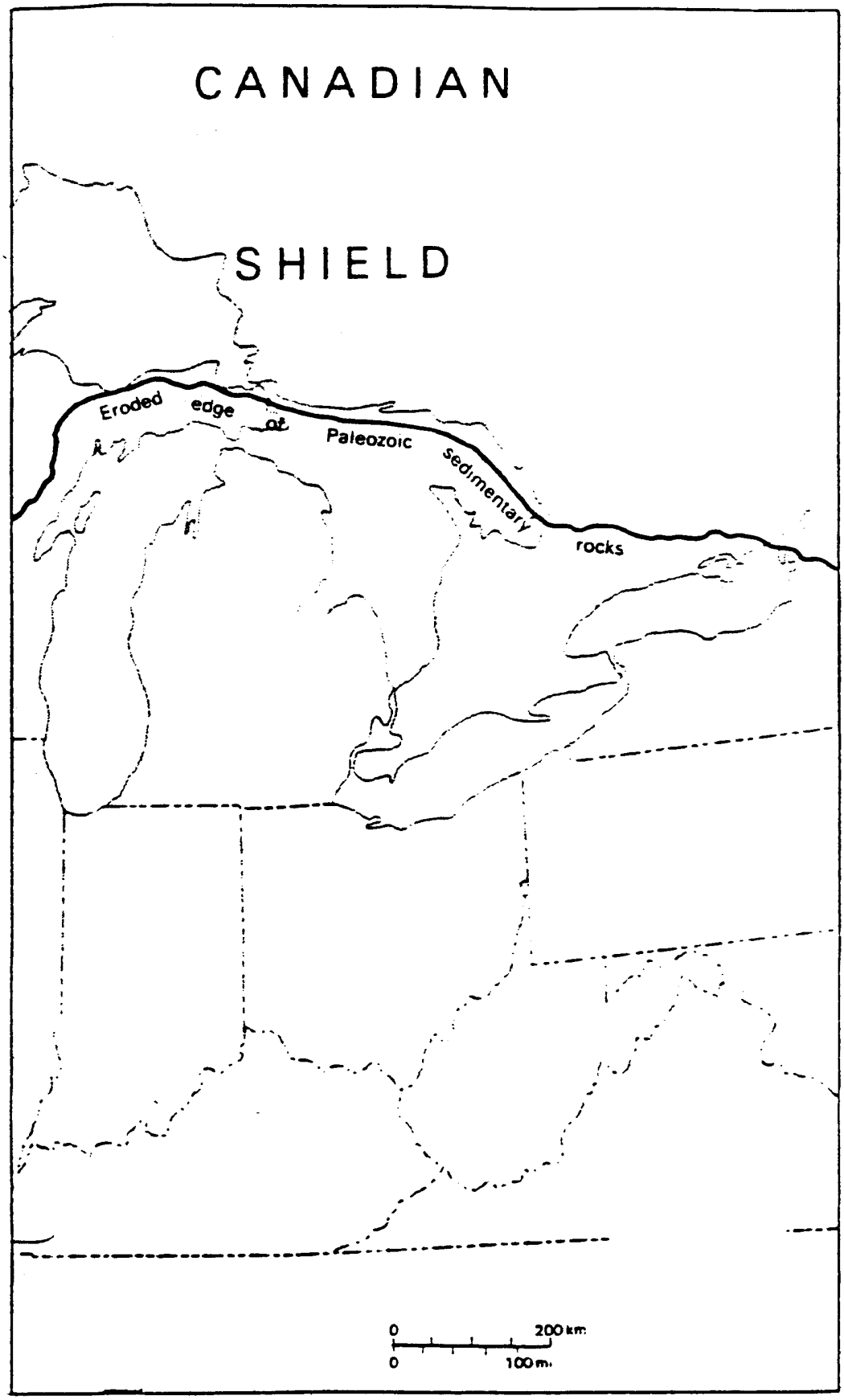


Figure 4. (Modified from Hansen, 1984.)

No physical break marks the boundary between the Cambrian and Ordovician. Sandstones were still being deposited near the Shield's edge, while limestones accumulated over most of the southern and marginal parts of the continent. In Ohio, this formation is termed the Knox Dolomite. Within this dolomite, sandstone deposits are also found. This author chooses not to break this formation into subdivisions. Fossil evidence has not been obtained in the Appalachian Basin as far as is known.

The Mt. Simon sandstone contains salt water in almost all wells drilled into this formation. The conclusion is that finding commercial hydrocarbons here is remote. This is also true for both the Rome and Conasauga Formations, unless the Rome Formation has local fracture porosity. The Kerbel Formation is considered potentially productive if it can be found structurally high and the overlying dolomite is impermeable (ref. 7, p. 67). Shows of gas in nearby Ohio counties of Stark, Mahoning, and Columbiana have been reported in the Kerbel. This author feels that the chances of commercial hydrocarbons being found in the Kerbel are minimal, but the sandstone should be checked in any deep test well.

The highest potential for finding commercial hydrocarbons in the Cambrian would be in the Knox dolomite formation, with its sandstone lenses. As of February 1977, 17 wells had penetrated the Cambrian in Ashtabula County. All were reported unproductive, with many being plugged back to the Grimsby sandstone of Silurian age. The Knox dolomite has produced sizable quantities of hydrocarbons throughout Ohio.

In March 1982, P.O.I. Energy, Inc., of Cleveland, Ohio, drilled a test well in Section 8 of New Lyme Township, Ashtabula County. Besides being a test well, the ultimate use of the well was to be for salt-water

injection. This company has chosen to keep its records of the well private. What is believed is they encountered a large pocket of gas, probably in the sandstones of the Knox Dolomite Formation. Reported production to the Ohio Division of Oil and Gas was 669,525,000 cubic feet of gas and 828 barrels of oil from March 1982 to December 1983. Subsequent offset wells only revealed slight uncommercial shows of gas. This was a highly profitable well for the company, but the only one reported from the Cambrian in Ashtabula County.

ORDOVICIAN AND THE TIPPECANOE SEQUENCE

The Sauk sea regressed after early Ordovician time although no evidence is recorded of this regression in the rock below the unconformity produced after the Sauk sea's withdrawal. However, a marked difference is seen in the fossil record from Early to Middle Ordovician time. A new transgressional cycle began in Middle Ordovician time and is termed the Tippecanoe sequence.

At the margins of the Shield, the transgressing Tippecanoe sea began reworking the sandstone that had previously been deposited by the Sauk sea.

In addition, newly eroded material was being deposited from the Shield to the north. As this was taking place in central and western parts of the craton, limestones interbedded with shales were being deposited along its eastern margins from Alabama to Quebec. This deposition has been called the Lower Chazy group. In Ashtabula County, the underlying Knox Dolomite may have been a structural high at the time of this deposition, for this basal Middle Ordovician deposit is absent or extremely thin if present.

Two major limestone deposits overlie the Lower Chazy group. In Ohio, these are termed the Black River and Trenton Limestones. Overlying these limestones are relatively little studied shales and limestones. These are extremely thick in Ashtabula County, over 1000 feet. The uppermost member of the Ordovician is the Queenston shale, which is also thick, approximately 700 feet in Ashtabula County. The Queenston is easily identified in drilling operations due to its large amounts of hematite in the sediments giving it a red coloration.

The potential for hydrocarbons in the Ordovician strata appears very slight at best. There has been no mention of hydrocarbons in the area from this system.

THE LOWER SILURIAN AND THE GRIMSBY SANDSTONE

By Silurian time, the Taconic orogeny was greatly influencing the study areas depositional environment. Large quantities of material were being supplied west and northwest from the uplift Taconic orogeny of eastern Pennsylvania and New York.

Overlying the Queenston Formation is the Whirlpool Sandstone. It was deposited in a marine environment and consists of silty sandstones, siltstones, and minor shales. Most literature described the Ordovician-Silurian contact as unconformable, but some refer to it as only a gradational contact (ref. 10, p. 34). Some believe that at least part of the Whirlpool is an eolian deposit, while the upper portion is a transgressive marine unit (ref. 13, p. 19) (ref. 10, p. 84). The Whirlpool is often termed the Medina by drillers in Ohio.

Above and gradational to the Whirlpool lies the Lower Cabot Head Shale with approximate thickness in the area of 35 feet. Small vertically discontinuous sand layers are found as lenses throughout this shale. This formation also is gradational upwards, and probably is a near shore sand-mud transitional zone.

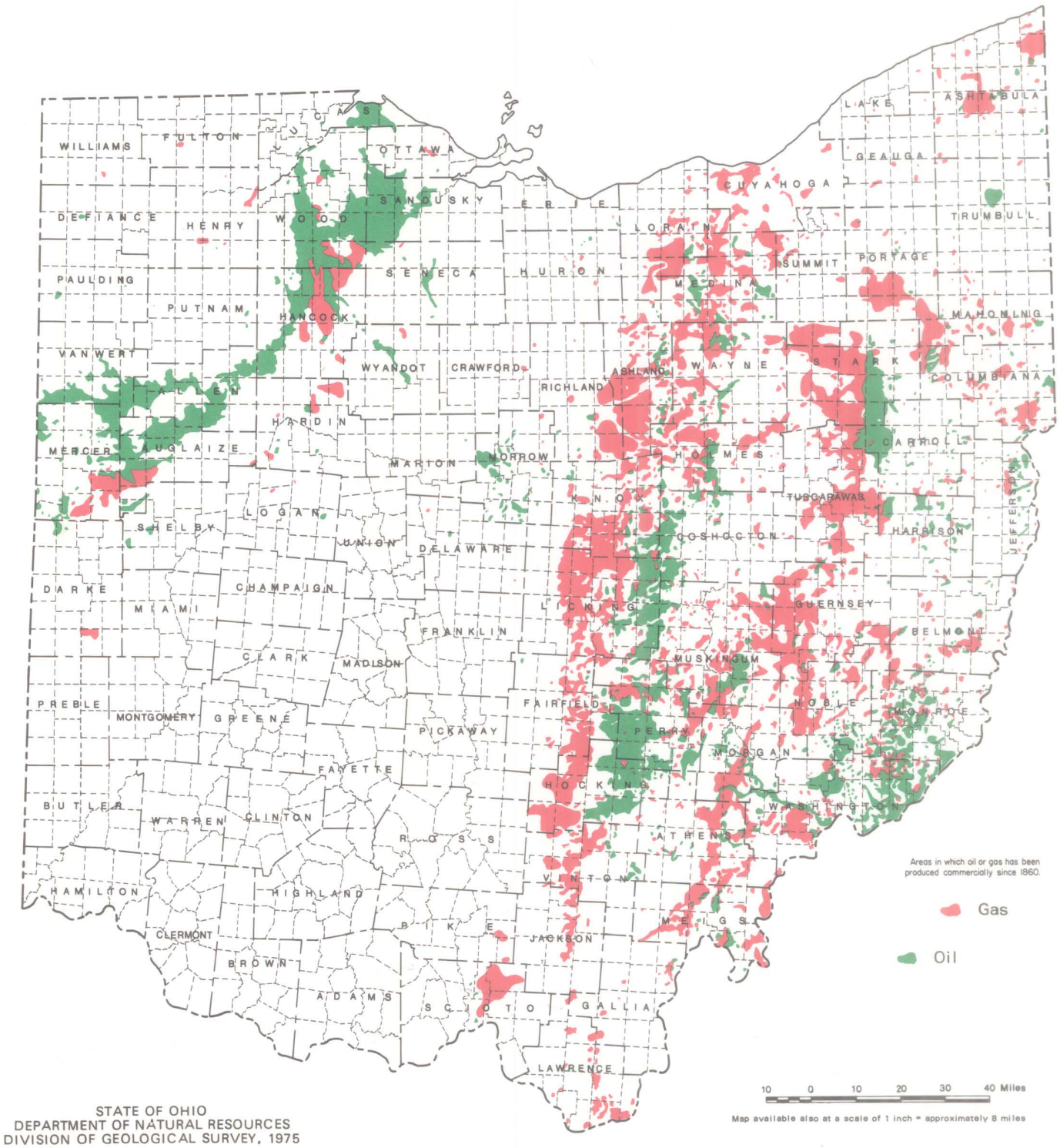
The Grimsby Formation lies above the Lower Cabot Head Shale and is the main target for drilling operations in Ohio. It consists of very clean quartz sandstone which interbeds with shales. These shales act as the cap rock, and in many places also serve as the source rock. Rafalowski (ref. 13, p. 49) concluded that this formation in Ashtabula County was still a marine facies off from a deltaic area. This author also chose to include Rafalowski's Thorold Sandstone with the Grimsby

Sandstone. This is done only because it is perforated and fractured in conjunction with the Grimsby sandstones in Ohio. The informal driller's name for the Grimsby in Ohio is the "Clinton". These offshore sandstones are considered a marine equivalent to the Tuscarora Sandstone of Pennsylvania.

The Upper Cabot Head Shale overlies the Grimsby Sandstone. In general, this is a silty shale sequence with interbedded siltstones and sandstones. It appears to be a fine-grained transitional zone from the lower clastic section and the overlying carbonate units.

These carbonate units are termed the Brassfield Limestone. They are still very silty in the lower parts from the influences of clastic deposition.

In looking at the oil and gas fields map of Ohio (fig. 5), two major fields show up in Ashtabula County. These are the Lenox and Bushnell fields. In the study area, the Grimsby sands have a very pronounced northwest-southeast trend, with a subordinate and much more subdued northeast-southwest trend. These appear to be the result of longshore movement of nearshore sand tongues and their associated channels. Rafalowski (fig. 6) put the majority of Ashtabula County in a low potential producing area. With the exception of the previously mentioned fields, recent drilling programs have shown Rafalowski to be correct. This author is in agreement with Rafalowski. Wells throughout the county are producing marginal amounts of gas. If the price of gas paid to producers doubled, this area may become a viable gas source. As it is, this area is, for the most part, uneconomical. Several small reservoirs are producing good quantities of gas, but these appear to be the exception,



OIL AND GAS FIELDS OF OHIO

Figure 5.

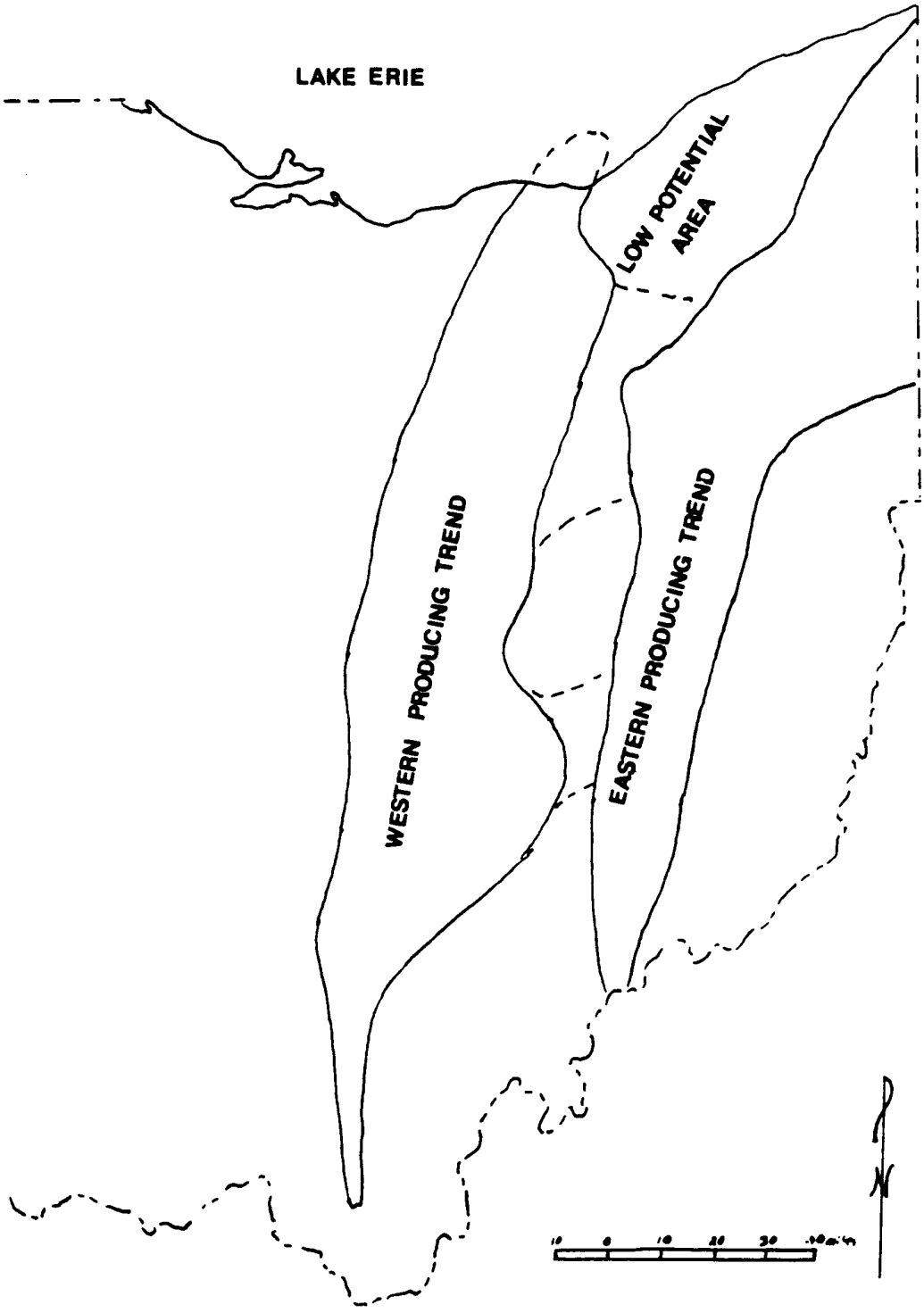


Figure 6. Producing trends of the Grimsby sandstone. (Taken from Rafalowski, 1982.)

not the rule. Four wells in central Kingsville Township were recently perforated in the Whirlpool Sandstone. They may be worth watching for additional hydrocarbon supplies. To date, no production has been reported.

MIDDLE AND UPPER SILURIAN

Changing from the clastic deposit of the Lower Silurian, the Middle Silurian is dominated by a thick carbonate series. The approximate extent of Middle Silurian deposits is shown in figure 7. The lower important carbonate of the system is the drillers' "Packer Shell". Possible equivalents may be the Reynales Dolomite or the Irondequoit Dolomite (ref 13, p. 25). It is mapable in the eastern half of Ohio and can be used to show local structural features just above the Grimsby Sandstone.

Ulteig (ref. 17, p. 15) included the next ascending formation, the Rochester Shale with the Lockport Group. He did so because there is no sharp contact between this shale and the overlying dolomites in most cases. The Lockport Group is always composed of dolomite, no anhydrite or limestone was observed in the study area (ref. 17, p. 16). It is considered to be biogenic in origin and be a classic example of Paleozoic bioherms. A conformable contact is observed in this area with the overlying Salina Group. A porosity zone encountered within the Lockport is termed in Ohio the "Newburg" dolomite. As of date, only salt water has been encountered in Ashtabula County. Gas had been encountered as near as Cuyahoga County to the west.

The basal member of the Salina Group is the Greenfield Formation or the "A Unit". It is a dolomite in the study area, but has been observed as a limestone west of here. Its thickness is 60 to 80 feet in Ashtabula County. The "B Unit" is placed at the base of the lowest evaporite salt deposit present in Ohio. In Lake County, it reaches thicknesses of 200

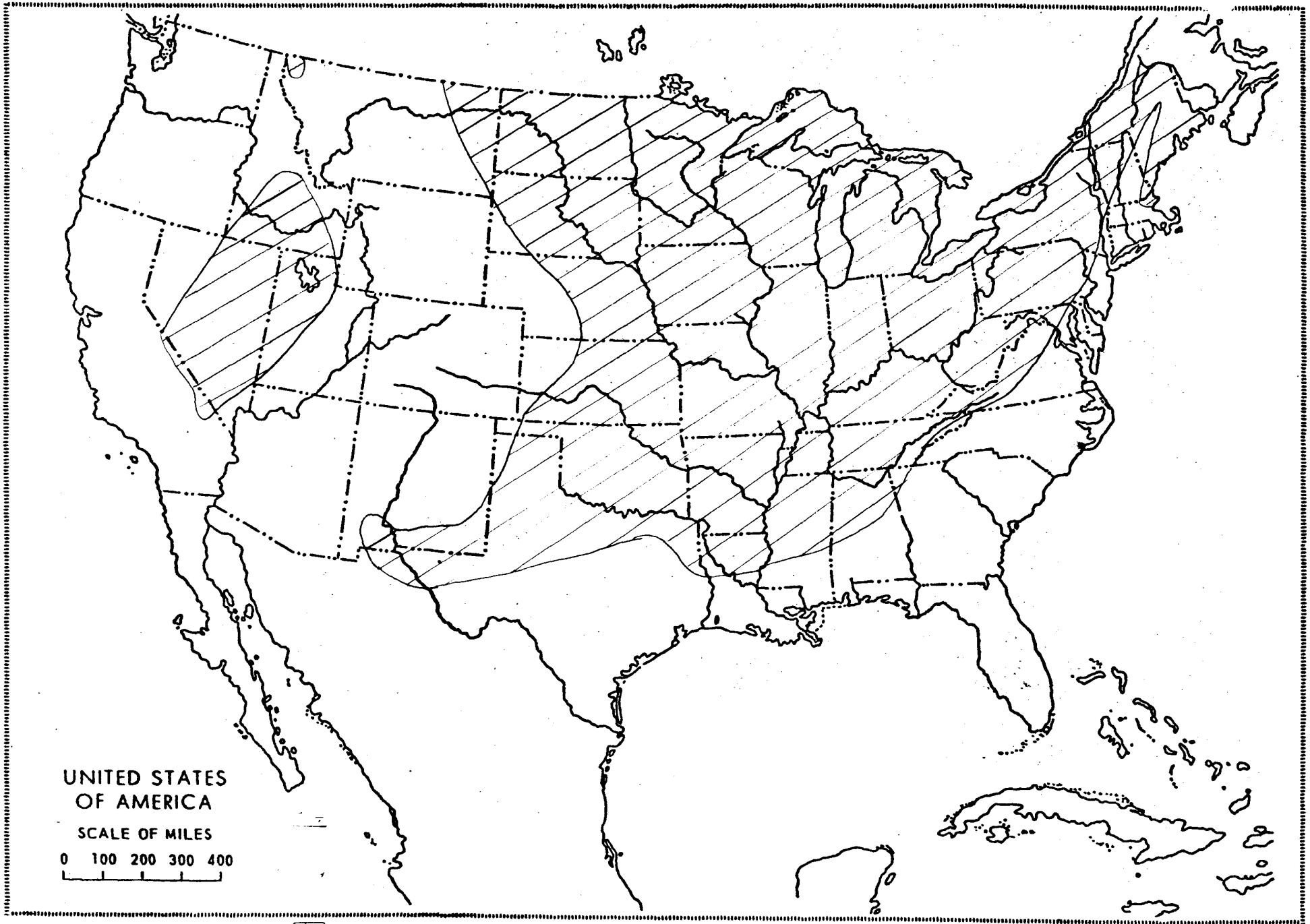


Figure 7. = Approximate extend of the Middle Silurian Series of the United States. (Modified from Clark and Stearn, 1968.)

feet. The "C Unit" is an overlying green shale unit of uniform thickness which is 30 to 40 feet.

The "D Unit" is an evaporite sequence with a thin shale parting its middle. The overlying "E Unit" differs throughout the study area, but an argillaceous dolomite or shale is always present at its top (ref. 17, p. 27). Four different evaporite zones are recognized in the "F Unit" of Ohio. It is broken up by many thin dolomites and shales. The "G Unit" was devised to separate the uppermost salt layer from the overlying carbonate rocks of the Bass Island Group.

The Middle and Upper Silurian deposits have no important hydrocarbon accumulations in Ashtabula County. It is of importance though, because of the large amounts of salt water encountered from the saline evaporite formations.

DEVONIAN CARBONATES AND SHALES

Throughout northeastern Ohio, the Silurian-Devonian contact appears unconformable. Finding its exact location can sometimes be difficult. In northeastern Ohio, various Silurian units can be shown to pinch-out and truncate below the Silurian-Devonian unconformity. In eastern Ohio, the interval displays transitional lithology, making it difficult to recognize a contact between the Bass Island of Silurian age and the Helderberg of Devonian age. Apparently in this area, there was continuous carbonate rock deposition from Late Silurian to Early Devonian time (ref. 17, p. 34).

The Oriskany sandstone is classified as the contact when the Helderberg is absent. This sand has been important in the oil and gas industry (fig. 8). It appears to be a reworked sandstone, the product of a transgression over an exposed area (ref. 17, p. 34). Other members of the "Onondaga Limestone" of Devonian age in northeastern Ohio include the Bois Blanc Formation and the Columbus Limestone.

Lying above this carbonate sequence, is a thick shale sequence. In Ohio, it can be divided into five principal radioactive zones (ref. 4, p. 2.15). In ascending order, these are (1) basal "lower" Olentangy Shale (Marcellus equivalent), (2) basal "upper" Olentangy Shale (Rhinestreet equivalent), (3) lower radioactive facies of the Huron Member (partial Dunkirk equivalent), (4) upper radioactive facies of the Huron Member, and (5) Cleveland Member. The Upper Devonian Shale sequences outcrop under glacial overburden in the majority of Ashtabula County (fig. 9).

During Middle Devonian time, the Acadian orogenic uplift started pouring sediments into the area. The Acadian uplift was centered in

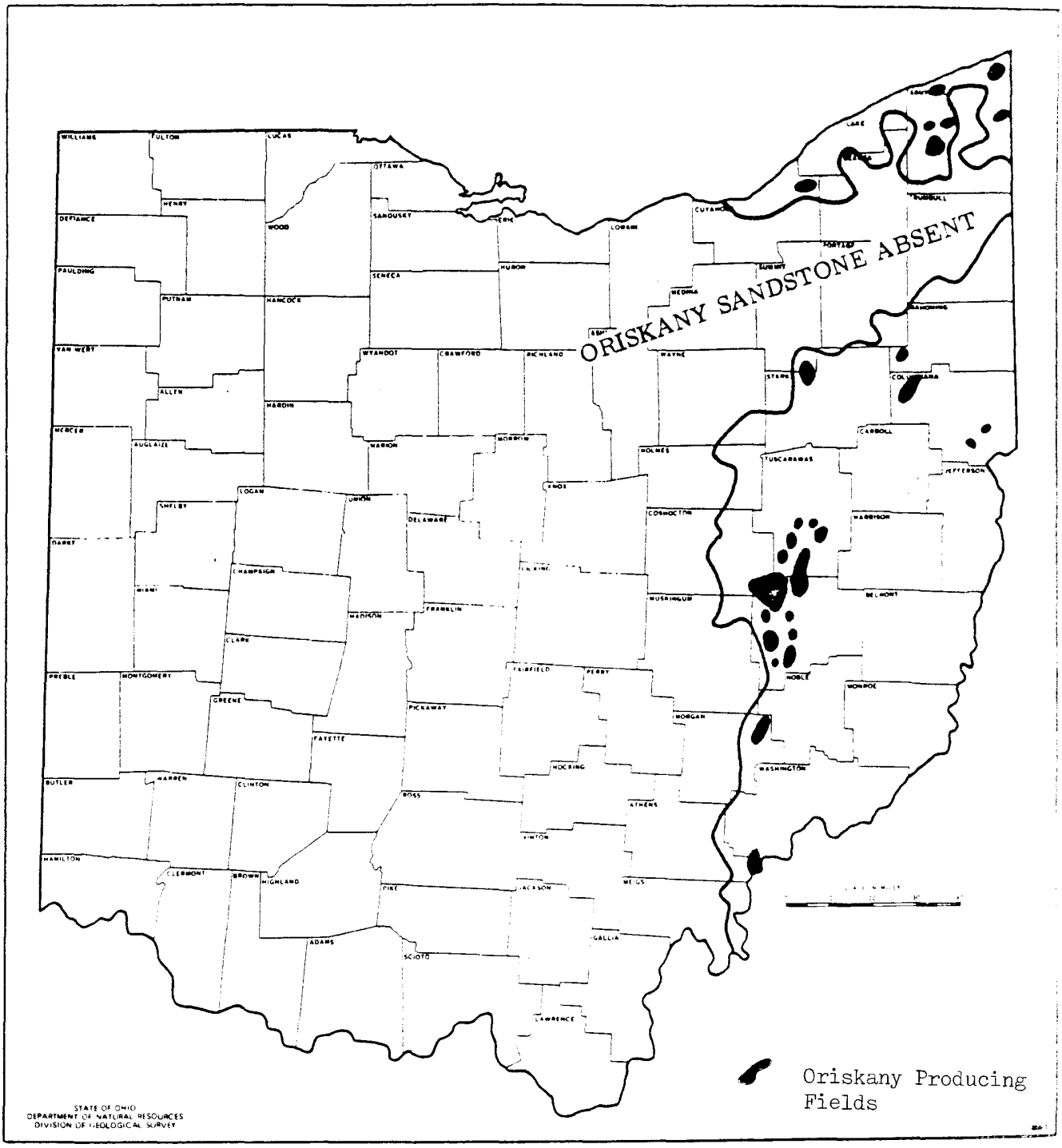


Figure 8. (Modified from Janssens, 1977.)

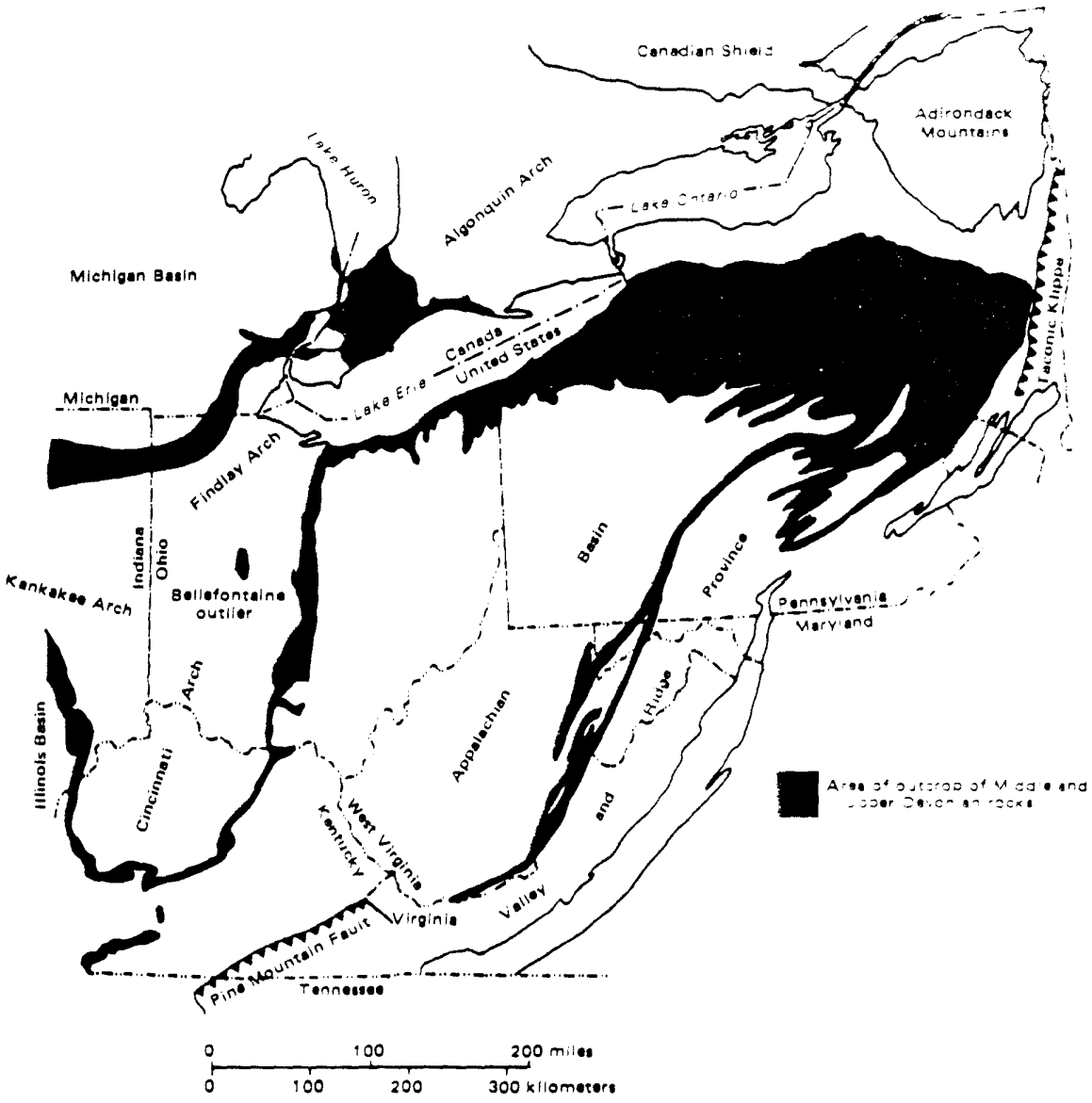


Figure 9. (Modified from Gray, 1982.)

the New England States and Maritime providences of Canada. Basinal subsidence helped keep this area in a shale depositional environment for the majority of the Middle and Upper Devonian Period. The Cleveland member is absent in Ashtabula County.

Production from the Oriskany Sandstone in the subject area has in general been prolific, but short-lived. Several local fields were ruined by salt water in only a few years, possibly indicating that the gas was trapped in the very top of this porous formation. While considered to be primarily stratigraphically controlled accumulations in this area, most of the local Oriskany fields appear to be associated with extremely subtle positive fold axes.

The Upper and Middle Devonian shales appear to have gas potential near Lake Erie. Two wells in northwestern Geneva Township blew out during drilling at a depth of approximately 650 feet. The Clinton Oil Company of Columbus, Ohio estimate that they lost 20,000 dollars per day over a four day period of marketable gas during one such blow out. Dozens of domestic gas wells are found along Lake Erie in Ashtabula and adjoining Lake counties. Natural production techniques have shown small daily flows, but the wells are long-lived. Production in this area is thought to be associated with natural fracturing due to on-loading and off-loading of glacial ice.

Due to the fact that in general the Devonian shales have low porosity and extremely low permeability, it is difficult to extract hydrocarbons. Until a new technique for increasing permeability is found, large quantities of gas are trapped in Devonian shales.

LOWER MISSISSIPPIAN OUTCROP

The Lower Mississippian System is represented in Ashtabula County in outcrops near the southern county border (fig. 10). In eastern Ashtabula and Trumbull counties, the basal unit is the Cussewago Sandstone. The Bedford Shale overlies this, and appears to be conformable in the east half of the state with the Ohio Shale.

The Berea Sandstone overlies the Bedford Shale. This is a widely produced zone throughout Ohio, but is at the surface in Ashtabula County, and shows no production possibilities. The depositional environment for this sand appears to be fluvial or tidal-channel fill. The exact direction of the source sediments is believed to be from the north, but this is uncertain.

The final formation found in Ashtabula county is the Sunbury Shale. This could also be the Orangeville Shale of the Cuyahoga Formation since these two are indistinguishable in this part of Ohio. It is a blue-gray shale in northern Ohio. Erosion has greatly reduced the original thickness of the Mississippian. Some members of the Mississippian have been completely eroded from this area.

THE MISSISSIPPIAN AND PENNSYLVANIAN SYSTEMS IN THE UNITED STATES

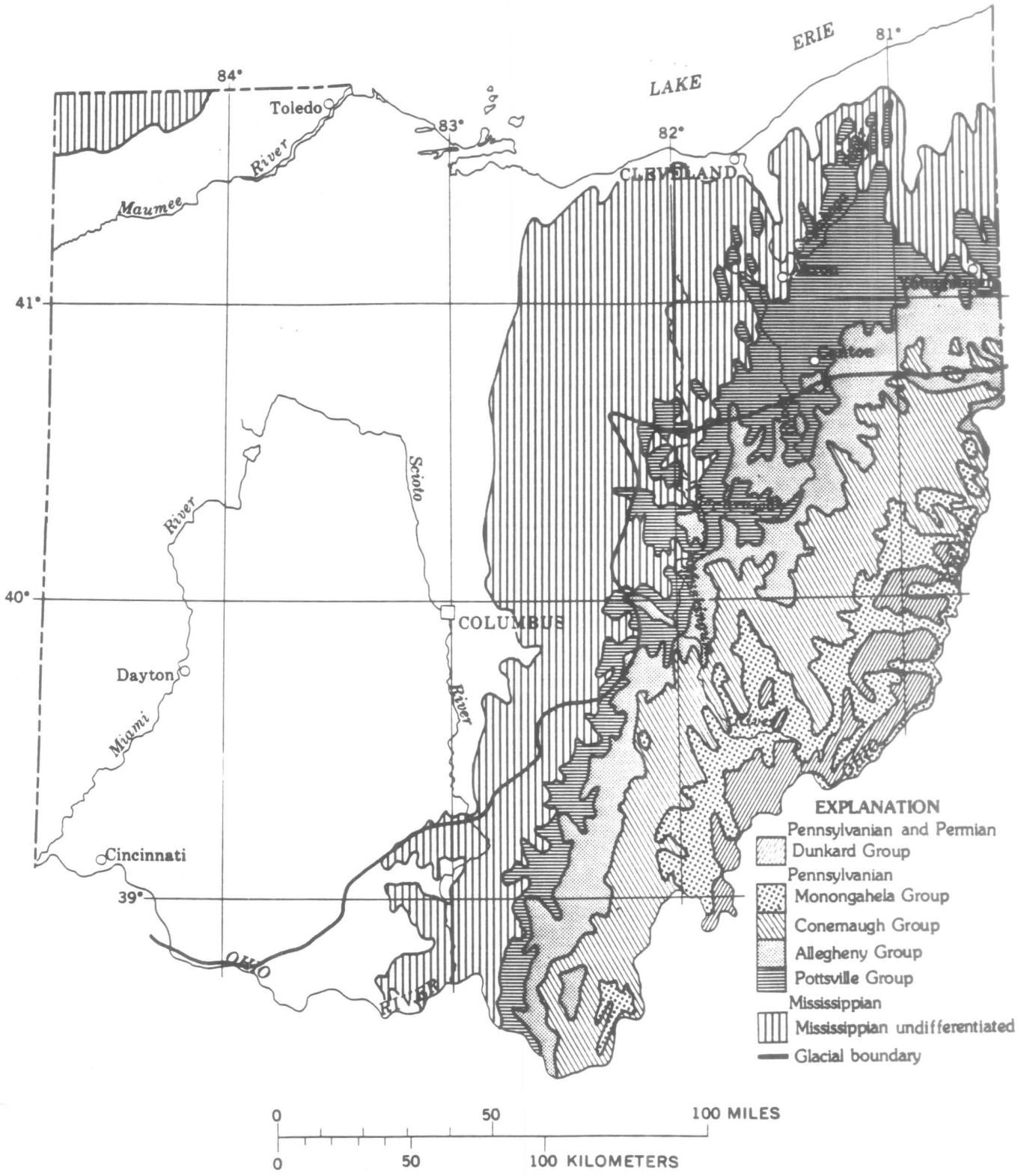


Figure 10. (Taken from Collins, 1979.)

SUMMARY AND CONCLUSIONS

Several years ago, the potential for large quantities of recoverable hydrocarbons in Ashtabula County was thought to exist. Recent intense drilling in the area has dampened this thought. Extensions of the Lenox and Bushnell Fields have met with only marginal success. Exploratory wildcat wells have only located small commercial reservoirs. With the present price being paid for natural gas, the Grimsby Sandstone will yield less than recoverable drilling costs for the majority of wells recently drilled in the area. This author predicts that drilling activities will taper off in the near future. If natural gas prices increase, this area may once again become active.

Over 20 wells have now been drilled into the Cambrian age rocks, with only one meeting with success. If the Precambrian structural surface could be mapped in the future, a better percentage of commercial wells may be realized. This at present is still a very risky zone in which to be drilling.

The Oriskany Sandstone still may yield several pools in the study area. It should be carefully watched when drilling to deeper formations. If strict production techniques are employed upon encountering one of these pools, large quantities of natural gas may be recovered from this zone.

The shallow Devonian shales near Lake Erie may also produce large quantities of natural gas. If new fracture zones can be located, very profitable wells will be drilled. The occurrence of these fracture zones will probably be hard to locate, making this a hard formation in which to drill exclusively.

BIBLIOGRAPHY

1.) Clark, T. H., and Stearn, C. W., 1968, Geological Evolution of North America; 2nd edition: The Ronald Press Co., 570 p.

2.) Collins, H. R., 1979, The Mississippian and Pennsylvanian (Carboniferous) Systems in the United States - Ohio: Geological Survey Professional Paper 1110-E, Washington, D. C.

3.) Fuller, J. Osborn, 1955, Source of Sharon Conglomerate of Northeastern Ohio: Geological Society of America Bulletin, v. 66, p. 159-175.

4.) Gray, J. D., et. al., 1982, An Integrated Study of the Devonian-Age Black Shales in Eastern Ohio: U. S. Department of Energy; Special Publication n. 12131-1399.

5.) Hansen, M. C., 1984, "Journey to the Center of the Earth" - The Aeromagnetic Anomaly Map of Ohio: Ohio Department of Natural Resources, Summer 1984 Newsletter, Columbus, Ohio.

6.) Honeycutt, M. and Majchszak, F. L., 1980, Net Thickness of the Radioactive Shale Facies in the Cleveland Member of the Ohio Shale: U. S. Department of Energy, Special Series n. 300.

7.) Janssens, A., 1977, Oil and Gas in Ohio - Past, Present, and Future: Ohio Department of Natural Resources; Paper read at the eighth annual Appalachian Petroleum Geology Symposium.

8.) Knight, W. V., 1969, Historical and Economic Geology of Lower Silurian Clinton Sandstone of Northeastern Ohio: American Association of Petroleum Geologists Bulletin, v. 53, n. 7, p. 1421-1452.

9.) Komar, C. A., 1981, Evaluation of Devonian Shale Potential in Pennsylvania: U. S. Department of Energy, Special Publications n. METC-199.

10.) McMullin, W. D., 1976, Subsurface Geology of the Lower Silurian Grimsby ("CLINTON") Sandstone of Ashtabula County, Ohio: Unpublished Master's Thesis, University of Texas at Arlington.

11.) Merkel, R. H., 1981, Well Log Formation Evaluation: American Association of Petroleum Geologists Continuing Education Course Note Series n. 14.

12.) Potter, P. A., et. al., 1983, Lithologic and Environmental Atlas of Berea Sandstone (Mississippian) in the Appalachian Basin: Appalachian Geologic Society Special Publication n. 1, 157 p.

13.) Rafalowski, J. W., 1982, The Gas Producing Potential of the Lower Silurian "Clinton" Sands Beneath Lake Erie, U.S.A.: Unpublished Master's Thesis, The Ohio State University, Columbus, Ohio.

14.) Richard, L. V., 1969, Gamma-Ray Logs and the Origin of Salt: Northern Ohio Geological Society, Inc.; Third Symposium on Salt, v. 1, p. 34-39, Cleveland, Ohio.

15.) Rudolph, L. A., 1982, Prospects for Natural Gas in Northern Ashtabula County, Ohio: unpublished.

16.) Smith, R., 1985, Personal communication, Professional Geologist, Columbus, Ohio.

17.) Ulteig, J. R., 1964, Upper Niagaran and Cuyugan Stratigraphy of Northeastern Ohio and Adjacent Areas: Ohio Department of Natural Resources, Report of Investigation n. 51, Columbus, Ohio, 48 p.